

Analyzing Frequency-Dependent Changes in Electrical Impedance Under Varying Intracranial Pressure Conditions

Brianna Botello, Biomedical Engineering

Mentor: Dr. Jit Muthuswamy, Phd

School of Biological and Health Systems Engineering

QR CODE

Introduction & Research Question

How does the impedance spectrum correlate with varying intracranial pressure (ICP) conditions?

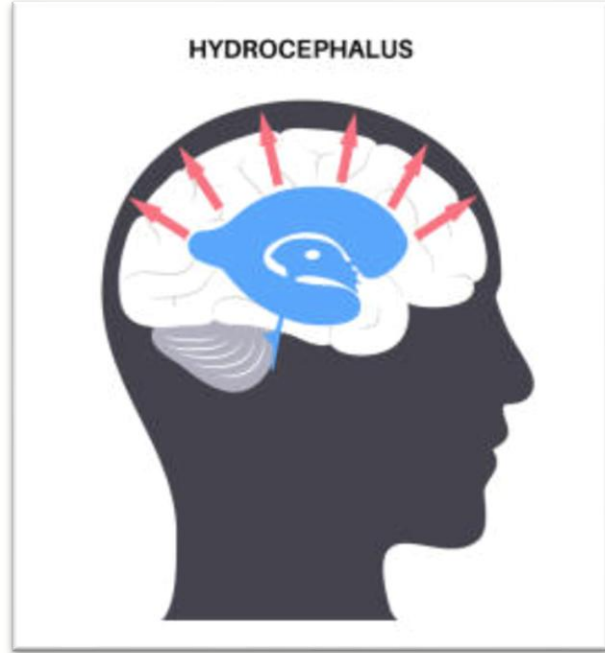


Figure 1. Accumulation of CSF resulting in elevated ICP

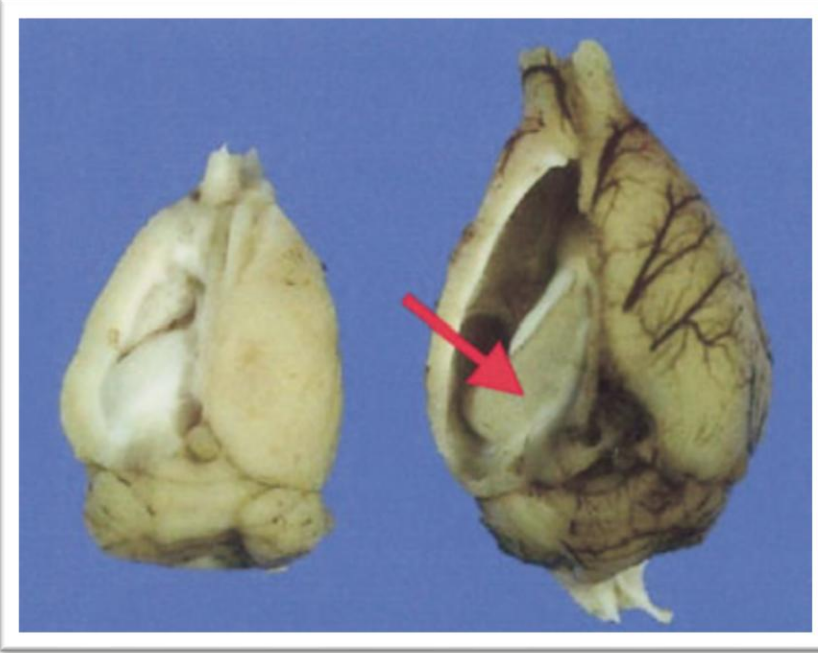


Figure 2. Comparison of normal and hydrocephalic rat brains reveals significant cerebral thinning, displacement of the hippocampus, and white matter atrophy [1].

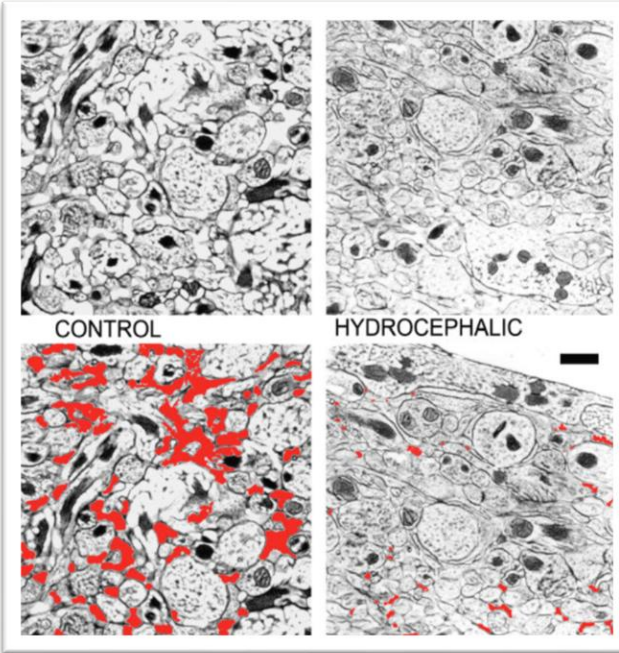


Figure 3. Compression of brain tissue in the extracellular space due to increased pressure and volume, leading to reduced extracellular fluid [2].

Project aims are to provide research for the development of more reliable and less invasive techniques for monitoring ICP in patients with intracranial shunts.

Materials & Methods

Materials:

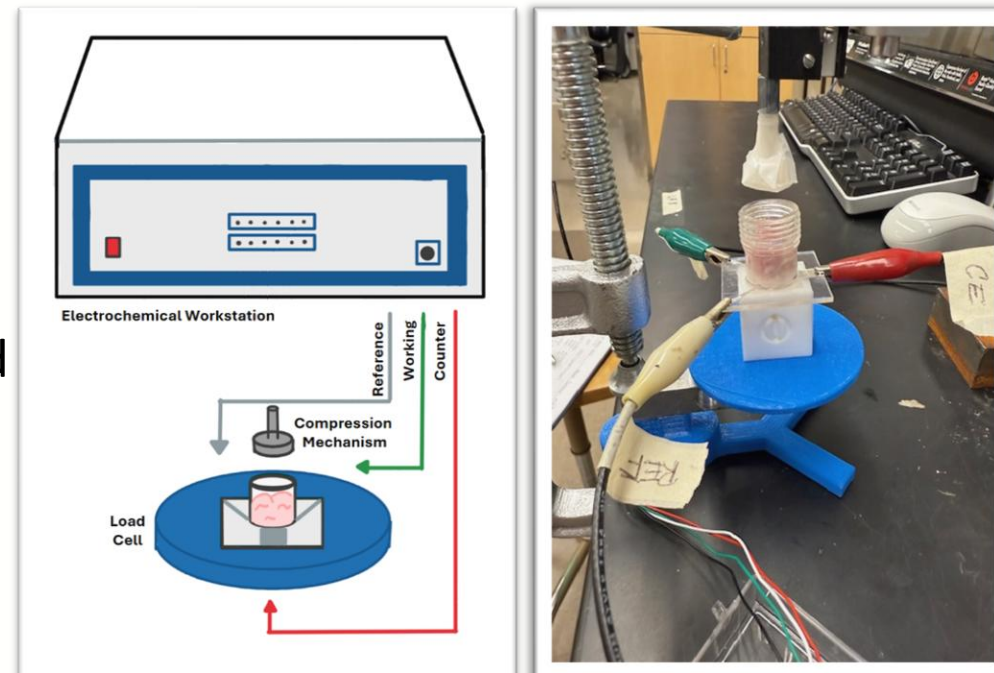
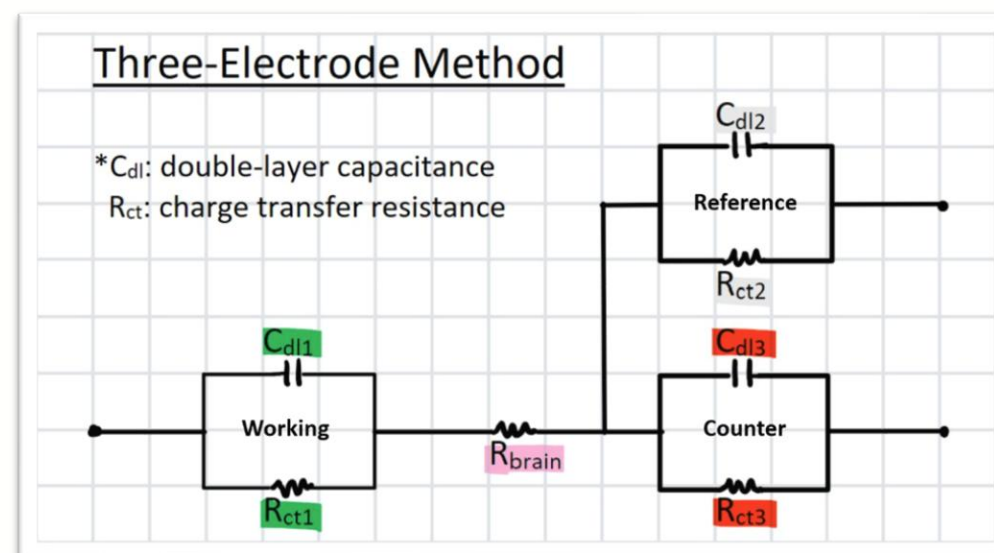
- Porcine Brain Tissue
- Artificial Cerebrospinal Fluid (ACSF)
- 1kg load cell + HX177 Amplifier + Arduino
- Electrochemical Workstation (CH Instruments)
- 3 Electrodes
- Silver Foil

Experimental Parameters:

- 1 mV
- 1-100k (Hz)
- 5, 10, 20, 30, 40 (mmHg)

Methods

Porcine tissue was confined in a small dish and subject to compression. An Arduino-based load cell was used to obtain the specific pressure measurements. For each compression, a frequency sweep was performed using the CH instruments 3-electrode method to obtain AC impedance values.



Results

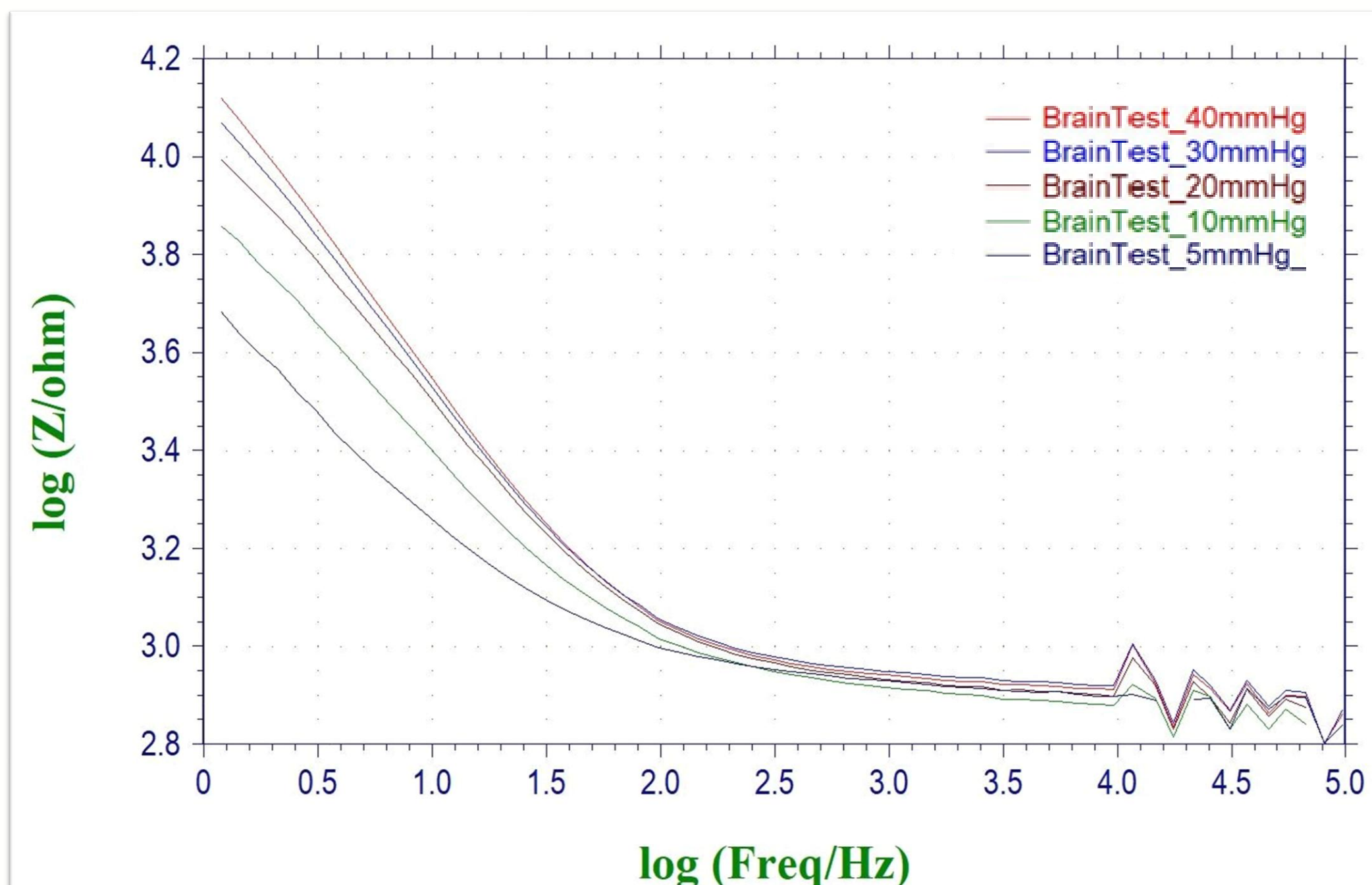


Figure 4. Log scale plot of the brain tissue impedance over a range of frequencies from 1 Hz – 100 kHz. The impedance was collected for pressures ranging from 5 mmHg to 40 mmHg. Impedance values were collected from porcine brain sample after thawing 24 hours in 4 °C. Measurements at 0 mmHg were noisy and subsequently excluded. Data collected for each pressure show distinct values until approximately 100 Hz, where they begin to merge. Slight noise in the high frequency range of 10 kHz – 100 kHz.

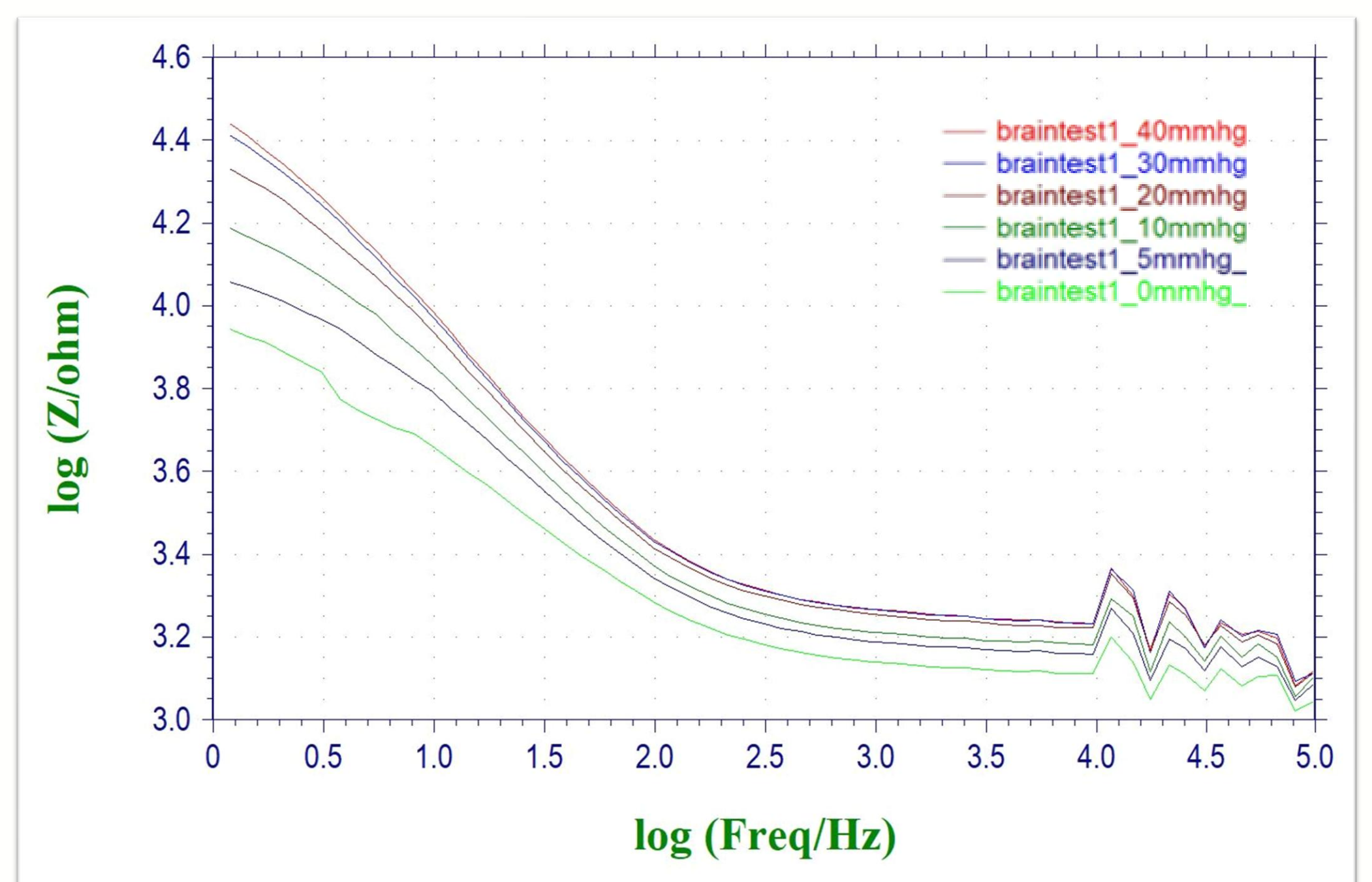


Figure 5. Log scale plot of the brain tissue impedance over the frequency range of 1 Hz – 100 kHz. Impedance data was collected for pressures in the range of 0 mmHg – 40 mmHg. The data was collected from a porcine brain sample thawed for 24 hours at 4 °C and soaked in ACSF 30 minutes prior to use. Maintained distinction for data collected at each pressure measurement. Still slight noise in the range of 10 kHz – 100 kHz.

Conclusion

Results indicate a correlation between pressure applied and measured impedance. As pressure applied to the brain tissue increased, so did the impedance. In the case of higher pressures (30 mmHg – 40 mmHg), there is seemingly a smaller increase in impedance values.

It can be determined that the low frequency range (1 Hz – 10 Hz) is most sensitive to pressure changes, showing greater difference for each pressure as compared to higher frequencies (100 Hz – 100 kHz). Measurements taken in the high frequency range merge more closely together.

This validates the brain tissue behaves in a capacitive nature, wherein high frequencies pass more easily, behaving as a short circuit. The three-electrode method is also a reliable method for collecting tissue impedance data.

Ensuring the brain tissue was stored properly and remained in a moist state through soaking in ACSF prior to use yielded better overall data.

As a result, impedance appears to be a promising method for ICP monitoring.

Future Directions

- Proceed with more realistic models for simulating intracranial pressure involving cadaver skull, fresh sheep brain, and inflatable balloon
- Improve noise reduction for data collected in the high frequency range (10 kHz – 100 kHz)

Acknowledgements

I am deeply grateful to Dr. Muthuswamy for his valuable expertise throughout this project. Special thanks to Michael D'Saachs for his guidance, and to Eliaz Garcia for assistance with troubleshooting. I also extend heartfelt thanks to my family for their constant support of my education.

References

- [1] M.R. Del Bigio, M.J. Wilson, and T. Enno, "Chronic hydrocephalus in rats and humans: White matter loss and behavior changes," *Annals of Neurology*, vol.53, no.3, pp.337–346, Feb.2003, doi: <https://doi.org/10.1002/ana.10453>.
- [2] M.R. Del Bigio and T.L. Enno, "Effect of hydrocephalus on rat brain extracellular compartment," *Cerebrospinal Fluid Research*, vol.5, no.1, Jul.2008, doi: <https://doi.org/10.1186/1743-8454-5-12>.